

WHAT IS CLAIMED IS:

1. A negative electrode for a lithium battery, comprising:

a lithium metal layer; and

a protective layer on the lithium metal layer, wherein the protective layer includes an
5 organosulfur compound.

2. The negative electrode of claim 1, wherein the organosulfur compound is a thiol
group-containing organosulfur compound.

3. The negative electrode of claim 1, wherein the organosulfur compound is a
monomer, dimer, trimer, oligomer, or a polymer.

10 4. The negative electrode of claim 1, wherein the organosulfur compound is selected
from the group consisting of 2,5-dimercapto-1,3,4-thiadiazole, bis(2-mercapto-ethyl)ether, N,N'-
dimethyl-N,N'-dimercaptoethylene-diamine, N,N,N',N'-tetramercapto-ethylenediamine,
polyethyleneimine, polyethyleneimine derivatives, 2,4,6-trimercaptotriazole, N,N'-dimercapto-
piperazine, 2,4-dimercaptopyrimidine, 1,2-ethanedithiol, bis(2-mercapto-ethyl)sulfide, and
15 mixtures thereof.

5. The negative electrode of claim 1, wherein the organosulfur compound is in an
amount ranging from about 50 to about 100 wt% of the protective layer.

6. The negative electrode of claim 1, wherein the protective layer further comprises
an electron conductive polymer to provide electron conductivity and for facilitation of cation
20 transfer.

7. The negative electrode of claim 6, wherein the electron conductive polymer is
selected from the group consisting of poly(aniline), poly(p-phenylene), poly(thiophene), poly(3-
alkylthiophene), poly(3-alkoxythiophene), poly(crowneherthiophene), poly(pyrrole), poly(N-

alkylpyrrole), poly(pyridine), poly(alkylpyridine), poly(2,2'-bipyridine), poly(dialkyl-2,2'-bipyridine), poly(pyrimidine), poly(dihydrophenanthrene), poly(quinoline), poly(isoquinoline), poly(1,2,3-benzothiadiazole), poly(benzimidazole), poly(quinoxaline), poly(2,3-diarylquinoxaline), poly(1,5-naphthyridine), poly(1,3-cyclohexadiene), poly(anthraquinone),
5 poly(Z-methylanthraquinone), poly(ferrocene), and poly(6,6'-biquinoline).

8. The negative electrode of claim 6, wherein the electron conductive polymer is an emeraldine base polymer.

9. The negative electrode of claim 6, wherein the electron conductive polymer is a doped polymer.

10. The negative electrode of claim 9, wherein the doped polymer is prepared by
10 reaction with a doping material, the doping material being selected from the group consisting of a halogen, a Lewis acid, a proton acid, a transition metal compound, an electrolytic anion, a sulfonic acid, O_2 , $XeOF_4(NO_2^+)(SbF_6^-)$, $(NO_2^+)(SbCl_6^-)$, $(NO_2^+)(BF_4^-)$, FSO_2OOSO_2F , $AgClO_4$, H_2IrCl_6 , and $La(NO_3)_3 \cdot 6H_2O$.

11. The negative electrode of claim 9, wherein the doped polymer is prepared by
15 reaction with a doping material, the doping material being a halogen selected from the group consisting of Cl_2 , Br_2 , I_2 , ICl , ICl_3 , IBr , and IF .

12. The negative electrode of claim 9, wherein the doped polymer is prepared by
reaction with a doping material, the doping material being a Lewis acid selected from the group
20 consisting of PF_5 , AsF_5 , SbF_5 , BF_3 , BCl_3 , BBr_3 , and SO_3 .

13. The negative electrode of claim 9, wherein the doped polymer is prepared by
reaction with a doping material, the doping material being a proton acid selected from the group
consisting of HF , HCl , HNO_3 , H_2SO_4 , $HClO_4$, FSO_3H , $ClSO_3H$, CF_3SO_3H , and an amino acid.

14. The negative electrode of claim 9, wherein the doped polymer is prepared by reaction with a doping material, the doping material being a transition metal compound selected from the group consisting of FeCl_3 , FeOCl , TiCl_4 , ZrCl_4 , HfCl_4 , NbF_5 , NbCl_5 , TaCl_5 , MoF_5 , WF_6 , WCl_6 , UF_6 , and LnCl_3 (Ln =lanthanoide)

5 15. The negative electrode of claim 9, wherein the doped polymer is prepared by reaction with a doping material, the doping material being an electrolytic anion selected from the group consisting of Cl^- , Br^- , I^- , Cl_4^- , PF_6^- , AsF_6^- , SbF_6^- , and BF_4^- .

16. The negative electrode of claim 9, wherein the doped polymer is prepared by reaction with a doping material, the doping material being a sulfonic acid having the formula $\text{R-SO}_3\text{H}$, where R is selected from the group consisting of a C_1 to C_{12} alkyl, a C_6 to C_{12} aryl, and an aralkyl group.

10 17. The negative electrode of claim 9, wherein the doped polymer is prepared by reaction with a doping material, the doping material being selected from the group consisting of doceyl benzene sulfonic acid, p-toluene sulfonic acid, benzene sulfonic acid, and octylbenzene sulfonic acid.

18. The negative electrode of claim 6, wherein the electron conductive polymer is a polymer having a doping ratio of at least about 30%.

19. The negative electrode of claim 6, wherein the electron conductive polymer is added in the protective layer in an amount of less than or equal to about 40 wt% of the protective layer.

20 20. The negative electrode of claim 1, wherein the protective layer further comprises an ionic conductive polymer to help facilitate transfer of lithium ions.

21. The negative electrode of claim 20, wherein the ionic conductive polymer is selected from the group consisting of poly(ethyleneoxide), poly(propyleneoxide), poly(ethylenesuccinate), poly(ethyleneadipate), poly(ethyleneimine), poly(epichlorohydrin), poly(β -propiolactone), poly(N-propylaziridine), poly(alkylenesulphide) where the alkylene is a C₂ to C₆ aliphatic hydrocarbon, poly(ethyleneglycoldiacrylate), poly(propyleneglycoldiacrylate), poly(ethyleneglycoldimethacrylate), and poly(propyleneglycoldimethacrylate).

22. The negative electrode of claim 21, wherein the ionic conductive polymer has a weight average molecular weight ranging from about 10,000 to about 600,000.

23. The negative electrode of claim 20, wherein the ionic conductive polymer is added in the protective layer at an amount of less than or equal to about 30 wt%.

24. A negative electrode for a lithium battery, comprising:

a lithium metal layer; and

a protective layer on the lithium metal layer, wherein the protective layer includes an organosulfur compound, an electron conductive polymer, and an ionic conductive polymer.

25. The negative electrode of claim 24, wherein the protective layer comprises the organosulfur compound in an amount ranging from about 50 to about 70 wt%, the electron conductive polymer in an amount ranging from about 20 to about 40 wt%, and the ionic conductive polymer in an amount ranging from about 10 to about 30 wt% of the protective layer.

26. A method for fabricating a negative electrode for a lithium battery, the method comprising the steps of:

adding an organosulfur compound to a solvent to prepare a slurry; and

coating the slurry on lithium metal to form an organosulfur compound-containing layer.

27. The method for fabricating a negative electrode of claim 26 further comprising the step of adding an electron conductive polymer and an ionic conductive polymer to the solvent.

28. The method for fabricating a negative electrode of claim 27, wherein the electron
5 conductive polymer is selected from the group consisting of poly(aniline), poly(p-phenylene),
poly(thiophene), poly(3-alkylthiophene), poly(3-alkoxythiophene), poly(crowneherthiophene),
poly(pyrrole), poly(N-alkylpyrrole), poly(pyridine), poly(alkylpyridine), poly(2,2'-bipyridine),
poly(dialkyl-2,2'-bipyridine), poly(pyrimidine), poly(dihydrophenanthrene), poly(quinoline),
poly(isoquinoline), poly(1,2,3-benzothiadiazole), poly(benzimidazole), poly(quinoxaline),
10 poly(2,3-diarylquinoxaline), poly(1,5-naphthyridine), poly(1,3-cyclohexadiene),
poly(anthraquinone), poly(Z-methylantraquinone), poly(ferrocene), and poly(6,6'-biquinoline).

29. The method for fabricating a negative electrode of claim 27, wherein the ionic
conductive polymer is selected from the group consisting of poly(ethyleneoxide),
poly(propyleneoxide), poly(ethylenesuccinate), poly(ethyleneadipate), poly(ethyleneimine),
15 poly(epichlorohydrin), poly(β -propiolactone), poly(N-propylaziridine), poly(alkylenesulphide)
poly(ethyleneglycoldiacrylate), poly(prophyleneglycoldiacrylate),
poly(ethyleneglycoldimethacrylate), and poly(prophyleneglycoldimethacrylate).

30. The method for fabricating a negative electrode of claim 27 further comprising
the step of adding a cross-linking initiator selected from the group consisting of diacyl peroxide
20 dialkyl, peroxide peroxy ester, tertiary alkyl hydroperoxide, peroxy ketal, peroxydicarbonate,
and an azo compound where the ionic conductive polymer is an acrylate-based polymer.

31. The method for fabricating a negative electrode of claim 27, further comprising
the step of adding a cross-linking initiator selected from the group consisting of dibenzoyl

peroxide, succinic acid peroxide, dilauroyl peroxide, didecanoyl peroxide, dicumyl peroxide, di-
t-butyl peroxide, 2,5-dimethyl-2,5-di-(t-butylperoxy)hexane, α -cumyl peroxy neodecanoate, 1,1-
dimethyl-3-hydroxybutyl peroxy-2-ethyl hexanoate, t-amylperoxy benzoate, t-butyl peroxy
pivalate, 2,5-dihydroperoxy-2,5 -dimethylhexane, cumene hydroperoxide, t-butyl hydroperoxide,
5 1,1-di-(t-amylperoxy)- cyclohexane, 2,2-di-(t-butyl peroxy)butane, ethyl 3,3-di-(t-butylperoxy)-
butylate, di(n-propyl) peroxy-dicarbonate, di(sec-butyl) peroxy- dicarbonate, di(2-ethyl
hexyl)peroxy-dicarbonate, and azobis isobutyronitrile.

32. The method for fabricating a negative electrode of claim 27, wherein the ionic
conductive polymer is an acrylate-based polymer, and wherein the slurry further comprises a
10 cross-linking facilitator.

33. The method for fabricating a negative electrode of claim 32, wherein the cross-
linking facilitator is selected from the group consisting of triethylamine, tributylamine, triethanol
amine, and N-benzyl dimethyl amine.

34. A method for fabricating a negative electrode for a lithium battery, comprising the
15 steps of:

adding an organosulfur compound to a positive electrode; and

performing at least one charge and discharge cycle for the battery having a negative
electrode, thereby forming a protective layer on a negative.

35. A lithium battery, comprising

20 a positive electrode including a positive active material selected from the group
consisting of a lithium-containing metal oxide, a lithium-containing calcogenide, a sulfur-based
material, and a conductive polymer;

a negative electrode comprising a lithium metal layer, and a protective layer on the lithium metal layer, wherein the protective layer includes an organosulfur compound; and an electrolyte between the positive and negative electrodes.

36. The lithium battery of claim 35, wherein the lithium battery is a lithium primary battery.

37. The lithium battery of claim 35, wherein the lithium battery is a lithium secondary battery.

38. The lithium battery of claim 35, wherein the electrolyte comprises a mixed organic solvent of 1,3-dioxolane, diglyme, sulforane, and dimethoxyethane.